CLAIMS

What is claimed is:

1. An ophthalmic lens comprising an optical zone, wherein the optical zone has a first surface and an opposite second surface and includes a coma-like wavefront aberration oriented vertically from the top to the bottom of the lens.

2. The ophthalmic lens of claim 1, wherein at least one of the first and second surface of the optical zone is asymmetrical, and wherein the optical zone has an optical power increasing from the top to the bottom of the optical zone.

3. The ophthalmic lens of claim 2, wherein at least one of the first surface and second surface of the optical zone is described by a spline-based mathematical function or a combination of two or more mathematical functions.

4. The ophthalmic lens of claim 3, wherein at least one of the first surface and second surface of the optical zone is described by a combination of two or more mathematical functions including Zernike polynomials.

5. The ophthalmic lens of claim 4, wherein the Zernike polynomials include at least one of third, fifth and seventh order coma-like terms based on the proposed OSA Zernike standard.

6. The ophthalmic lens of claim 3, wherein at least one of the first surface and second surface of the optical zone is described by a combination of a biconic mathematical function with at least one vertically oriented coma-like Zernike term or equivalents thereof.

7. The ophthalmic lens of claim 6, wherein the magnitude of the vertically oriented Zernike coma coefficient, based on the proposed OSA Zernike standard, is between about 0.1 μm RMS (root-mean-square) and about 2 μm RMS at a 6 mm diameter optical zone.

8. The ophthalmic lens of claim 6, wherein said at least one vertically oriented coma-like Zernike term is a vertically oriented third order coma-like Zernike term Z7 (based on the proposed OSA Standard Zernike Polynomials), and wherein said at least one of the first surface and second surface of the optical zone is described by the following equation:

$$Z(\rho,\theta) := \frac{(c_x \bullet r^2 + c_y \bullet r^2)}{[1+\sqrt{1-(1+k_x)\bullet(c_x{}^2 \bullet r^2)-(1+k_y)\bullet c_y{}^2 \bullet r^2\}}]} + Z7 \bullet \sqrt{8} \bullet (3 \bullet \rho^2 - 2) \bullet \rho \bullet \sin(\theta)$$

wherein,

Z(ρ, θ) describes the optical zone,

c_x is the curvature (reciprocal of the radius) in x' direction,

c_y is the curvature (reciprocal of the radius) in y' direction,

k_xx is a conic constant in x' direction,

k_y is a conic constant in y' direction,

r equals to the semi diameter of the at least one surface,

ρ is equivalent to the normalized pupil coordinate (r/rmax),

θ is angular component,

Z7 is coefficient of vertical coma in terms of RMS μm.

9. The ophthalmic lens of claim 6, wherein said at least one vertically oriented coma-like Zernike term is a vertically oriented fifth order coma-like Zernike term Z17.

10. The ophthalmic lens of claim 6, wherein said at least one vertically oriented coma-like Zernike term is a vertically oriented seventh order coma-like term Z31.

11. The ophthalmic lens of claim 3, wherein at least one of the first surface and second surface of the optical zone is described by a combination of a conic mathematical function with at least one vertically oriented coma-like Zernike term or equivalents thereof.

12. The ophthalmic lens of claim 11, wherein said at least one vertically oriented coma-like Zernike term is a vertically oriented third order coma-like Zernike term Z7, Z17 or seventh order coma-like term Z31 (based on the proposed OSA Standard Zernike Polynomials).

13. The ophthalmic lens of claim 3, wherein at least one of the first surface and second surface of the optical zone is described by one or more spline-based mathematical functions.

14. The ophthalmic lens of claim 3, wherein the ophthalmic lens is a contact lens.

15. The ophthalmic lens of claim 14, wherein the contact lens comprises one or more orientation or stabilization features.

16. The ophthalmic lens of claim 15, wherein said one or more orientation/stabilization features are selected from the group consisting of: a prism ballast or the like that uses a varying thickness profile to control the lens orientation; a faceted surface in which parts of the lens geometry is removed to control the lens orientation; a ridge feature which orients the lens by interacting with the eyelid; double slab-off features which have a top slab-off zone and a bottom slab-off zone zones to maintain the lens orientation on the eye; and non-prism ballast features in the peripheral zone of the lens, the peripheral zone surrounding the optical zone of the lens.

17. The ophthalmic lens of claim 15, wherein the contact lens comprises on the anterior surface of the lens a ramped ridge zone which is disposed below the optical zone and includes an upper edge, a lower ramped edge, a latitudinal ridge that extends outwardly from the anterior surface, and a ramp that extends dowardly from the lower ramped edge and has a curvature or slope that provides a varying degree of interaction between the ramped ridge zone and the lower eyelid of an eye depending on where the lower eyelid strikes the ramped ridge zone.

18. The ophthalmic lens of claim 15, wherein the contact lens comprises:

a posterior surface; and

an opposite anterior surface including a vertical meridian, a horizontal meridian, an anterior optical zone, a blending zone extending outwardly from the anterior optical zone, a peripheral zone surrounding the blending zone, and an edge zone circumscribing and tangent to the peripheral zone,

wherein the anterior optical zone is one of the first and second surface of the optical zone, wherein the blending zone has a surface which ensures that the peripheral zone, the blending zone and the anterior optical zone are tangent to each other, wherein the peripheral zone has a surface that, in combination with the posterior surface, provides in the peripheral zone of the lens a thickness profile which is characterized (1) by having a lens thickness which increases progressively from the top of the lens downwardly along each of the vertical

meridian and lines parallel to the vertical meridian until reaching a maximum value at a position between the anterior optical zone and the edge zone and then decreases to the edge of the edge zone, or (2) by having a mirror symmetry with respect to a plane cutting through the vertical meridian, by having a substantially constant thickness in a region around the horizonal meridian and by having a thickness which decreases progressively from the horizontal meridian to the top or bottom of the contact lens along each of the vertical meridian and lines parallel to the vertical meridian.

19. The ophthalmic lens of claim 3, wherein the ophthalmic lens is a phakic or aphakic intraocular lens.

20. The ophthalmic lens of claim 19, wherein the phakic or aphakic intraocular lens comprises haptics.

21. A customized ophthalmic lens, comprising an optical zone which, alone or in combination with the optics of an eye, produce a vertically oriented coma-like wavefront aberration.

22. The customized ophthalmic lens of claim 21, wherein the optical zone does not correct the vertically oriented coma-like aberrations of the eye while correcting or minimizing wavefront aberration other than the vertically oriented coma-like aberrations.

23. The customized ophthalmic lens of claim 22, wherein the optical zone has a vertically oriented coma-like wavefront aberration introduced to reach a desired overall amount of vertically oriented coma-like wavefront aberrations of the ophthalmic lens plus the eye.

24. The customized ophthalmic lens of claim 21, correct all or parts of each of dominant high order wavefront aberrations of the eye so as to obtain a vertically oriented coma-like wavefront aberration.

25. The customized ophthalmic lens of claim 24, wherein the optical zone has a vertically oriented coma-like wavefront aberration introduced to reach a desired overall amount of vertically oriented coma-like wavefront aberrations of the ophthalmic lens plus the eye.

26. The customized ophthalmic lens of claim 21, wherein the ophthalmic lens is a contact lens.

27. The customized ophthalmic lens of claim 26, wherein the posterior surface of the contact lens has a geometry to accommodate the corneal topography of the eye or a corneal topography statistically represent a segment of population.

28. The customized ophthalmic lens of claim 26, wherein the contact lens comprises one or more orientation/stabilization features.

29. The customized ophthalmic lens of claim 28, wherein said one or more orientation/stabilization features are selected from the group consisting of: a prism ballast or the like that uses a varying thickness profile to control the lens orientation; a faceted surface in which parts of the lens geometry is removed to control the lens orientation; a ridge feature which orients the lens by interacting with the eyelid; double slab-off features which have a top slab-off zone and a bottom slab-off zone zones to maintain the lens orientation on the eye; and non-prism ballast features in the peripheral zone of the lens, the peripheral zone surrounding the optical zone of the lens.

30. The customized ophthalmic lens of claim 29, wherein the contact lens comprises on the anterior surface of the lens a ramped ridge zone which is disposed below the optical zone and includes an upper edge, a lower ramped edge, a latitudinal ridge that extends outwardly from the anterior surface, and a ramp that extends dowardly from the lower ramped edge and has a curvature or slope that provides a varying degree of interaction between the ramped ridge zone and the lower eyelid of an eye depending on where the lower eyelid strikes the ramped ridge zone.

31. The customized ophthalmic lens of claim 29, wherein the anterior surface of the contact lens includes a vertical meridian, a horizontal meridian, an anterior optical zone, a blending zone extending outwardly from the anterior optical zone, a peripheral zone surrounding the blending zone, and an edge zone circumscribing and tangent to the peripheral zone, wherein the anterior optical zone is one of the first and second surface of the optical zone, wherein the blending zone has a surface which ensures that the peripheral zone, the blending zone and the anterior optical zone are tangent to each other, wherein the peripheral zone has a surface

that, in combination with the posterior surface, provides in the peripheral zone of the lens a thickness profile which is characterized (1) by having a lens thickness which increases progressively from the top of the lens downwardly along each of the vertical meridian and lines parallel to the vertical meridian until reaching a maximum value at a position between the anterior optical zone and the edge zone and then decreases to the edge of the edge zone, or (2) by having a mirror symmetry with respect to a plane cutting through the vertical meridian, by having a substantially constant thickness in a region around the horizonal meridian and by having a thickness which decreases progressively from the horizontal meridian to the top or bottom of the contact lens along each of the vertical meridian and lines parallel to the vertical meridian.

32. The customized ophthalmic lens of claim 21, wherein the ophthalmic lens is a phakic intraocular lens or an aphakic intraocular lens.

33. A method for making an ophthalmic lens, comprising the step of producing the ophthalmic lens by a manufacturing means, wherein the ophthalmic lens comprises an optical zone, the optical zone having a first surface and an opposite second surface and including a coma-like wavefront aberration oriented vertically from the top to the bottom of the lens.

34. The method of claim 33, wherein at least one of the first and second surface of the optical zone is asymmetrical, and wherein the optical zone has an optical power increasing from the top to the bottom of the optical zone.

35. The method of claim 34, wherein at least one of the first and second surface of the optical zone is asymmetrical, and wherein the optical zone has an optical power increasing from the top to the bottom of the optical zone.

36. The method of claim 35, wherein at least one of the first surface and second surface of the optical zone is described by a spline-based mathematical function or a combination of two or more mathematical functions.

37. The method of claim 36, wherein at least one of the first surface and second surface of the optical zone is described by a combination of two or more mathematical functions including Zernike polynomials.

39. The method of claim 37, wherein the Zernike polynomials include at least one of third, fifth and seventh order coma-like terms based on the proposed OSA Zernike standard.

40. The method of claim 39, wherein said at least one of third, fifth and seventh order coma-like Zernike term is a vertically oriented third order coma-like Zernike term Z7, fifth order coma-like Zernike term Z17 or seventh order coma-like term Z31 based on the proposed OSA Standard Zernike Polynomials.

41. The method of claim 36, wherein at least one of the first surface and second surface of the optical zone is described by one or more spline-based mathematical functions.

42. The method of claim 36, wherein the manufacturing means is a computer-controllable manufacturing device.

43. The method of claim 42, wherein the computer controllable manufacturing device is a numerically controlled lathe.

44. A method for minimizing or correcting presbyopia, comprising the step of reshaping a cornea of an eye to produce a vertically oriented coma-like wavefront aberration.

45. The method of claim 44, wherein the reshaped cornea has an optical zone, wherein the optical zone is asymmetrical, and has an optical power increasing from the top to the bottom of the optical zone.

46. The method of claim 45, wherein the optical zone is described by a spline-based mathematical function or a combination of two or more mathematical functions.

47. The method of claim 46, wherein the optical zone is described by a combination of two or more mathematical functions including Zernike polynomials.

48. The method of claim 47, wherein the Zernike polynomials include at least one of third, fifth and seventh order coma-like terms based on the proposed OSA Zernike standard.

49. The method of claim 48, wherein said at least one of third, fifth and seventh order coma-like Zernike term is a vertically oriented third order coma-like Zernike term Z7, fifth order coma-like Zernike term Z17 or seventh order coma-like term Z31 based on the proposed OSA Standard Zernike Polynomials.

50. The method of claim 49, wherein the optical zone is described by a combination of a biconic mathematical function with at least one of the vertically oriented coma-like Zernike terms or equivalents thereof.

51. The method of claim 50, wherein the magnitude of the vertically oriented Zernike coma coefficient, based on the proposed OSA Zernike standard, is between about 0.1 μm RMS (root-mean-square) and about 2 μm RMS at a 6 mm diameter optical zone.

52. The method of claim 50, wherein said at least one of the vertically oriented coma-like Zernike terms is a vertically oriented third order coma-like Zernike term Z7 based on the proposed OSA Standard Zernike Polynomials, and wherein the optical zone is described by the following equation:

$$Z(\rho,\theta) := \frac{(c_x \bullet r^2 + c_y \bullet r^2)}{[1+\sqrt{1-(1+k_x)\bullet(c_x^{\,2}\bullet r^2)-(1+k_y)\bullet c_y^{\,2}\bullet r^2\}}]} + Z7\bullet\sqrt{8}\bullet(3\bullet\rho^2-2)\bullet\rho\bullet\sin(\theta)$$

wherein,

Z(ρ, θ) describes the optical zone,

c_x is the curvature (reciprocal of the radius) in x' direction,

c_y is the curvature (reciprocal of the radius) in y' direction,

k_xx is a conic constant in x' direction,

k_y is a conic constant in y' direction,

r equals to the semi diameter of the at least one surface,

ρ is equivalent to the normalized pupil coordinate (r/rmax),

θ is angular component,

Z7 is coefficient of vertical coma in terms of RMS μm.

53. The method of claim 49, wherein the optical zone is described by a combination of a conic mathematical function with at least one vertically oriented coma-like Zernike term or equivalents thereof.

54. The method of claim 53, wherein wherein said at least one vertically oriented coma-like Zernike term is a vertically oriented third order coma-like Zernike term Z7, Z17 or seventh order coma-like term Z31 based on the proposed OSA Standard Zernike Polynomials.

55. The method of claim 49, wherein the optical zone is described by one or more spline-based mathematical functions.

56. The method of claim 46, wherein the step of reshaping occurs by ablating the cornea.

57. The method of claim 56, wherein the step of ablating occurs by controlling energy distribution of a laser beam on an optical surface of the cornea.

58. The method of claim 56, wherein the step of ablating occurs by controlling a flying spot laser pattern on an optical surface of the cornea.

59. The method of claim 56, wherein the step of ablating occurs by controlling angle of ablation on an optical surface of the cornea.